# Latest Trends in Recommender Systems applied in the medical domain: A Systematic Review

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## ABSTRACT

Recommender systems use algorithms to provide users with product or service recommendations. In recent times, these systems have been using Artificial Intelligence algorithms. However, choosing a suitable AI algorithm for a recommender system is difficult because of the number of algorithms described in the literature. Researchers and practitioners developing recommender systems are left with little information about the current approaches in algorithm usage. Moreover, the development of recommender systems using AI algorithms often faces problems and raises questions that must be resolved. In this context developing recommender system in the medical domain are presented as complementary tools in decision-making processes in healthcare services, it allows to increase the usability of technologies and reduce information overload in processes. This paper presents a systematic review of the literature that analyze the use of AI algorithms in recommender system and identify new research opportunities.

The goals of this study are to (i) identify latest trends in the use or research of AI algorithms in recommender system applied in the medical domain;(ii)identify open questions in the use or research of AI algorithms, and (iii)assist new researchers to position new research activity in this domain appropriately.

## CCS CONCEPTS

- **Computing methodologies** → Artificial intelligence ; Machine Learning.
- **Information Systems** → Recommender System.



NISS2020, March 31-April 2, 2020, Marrakech, Morocco © 2020 Association for Computing Machinery. ACM ISBN 978-1-4503-7634-1/20/03…$15.00
https://doi.org/10.1145/3386723.3387860

**Keywords:** systematic review; recommender system; AI algorithms; Collaborative Filtering.

**Areas Covered:** The main goal of this paper is to introduce the main research or methods of the Artificial Intelligence algorithm in Recommender System and provide relevant learning and reference for relevant researchers. Meantime, it summarizes the main problems existing in these methods and provides better guidance for future research.

## 1. INTRODUCTION

The goal of Artificial Intelligence (AI) is to develop systems that can exhibit intelligence similar to human beings and AI is applied to many fields [6]. Artificial intelligence is widely used in identifying human diseases and their treatments. Every day, millions of people get sick and receive treatments. However, there is no system that can accept the information related to the symptoms, diseases, timelines, medical procedures, and medications experienced by various people and use this information to recommend treatments [3] and to predict possible future diseases to other similar people [6]. Recommender systems play an important role in decision making, helping users especially patients to minimize risks diseases.

There are many ways AI can be achieved some of them are as follows: (Machine learning, Natural Language Processing, Vision, Robotics, Autonomous Vehicles) (figure 3) [7]. The potential application of AI algorithms is vast and the field looks very promising. AI algorithms are being used in Recommender System to provide users with better recommendations.

A recommender system has the capability to anticipate medical treatments based on the patient's preferences. This system can be implemented based on a patient's profile or a symptom profile given by the patient.

This paper provides a systematic review to investigate how AI algorithms used in RSs are studied and used; and what are the newest trends in AI algorithm research and development. It is expected that, with this systematic review, researchers can obtain more information about the RS field, and make better implementation or research decision. The goals of this study are to (i) identify latest trends in the use or research of AI algorithms in recommender system applied in the medical domain;(ii)identify open questions in the use or research of AI algorithms, and (iii)assist new researchers to position new research activity in this domain appropriately. This paper is organized as follows: Section 2 presents an overview of the basic concept on Recommender system and artificial intelligence;

Section 3 explains the systematic review protocol, and section 4 explains the results of this study. Section 5 presents a conclusion and opportunities for future work.

## 2. Theoretical background:

This section gives an overview of two main research fields related to this article, namely recommender systems and Artificial Intelligence.

### 2.1 Preliminaries and Basic Concepts of Recommender System:

#### *2.1.1 Recommender System:*

Recommender systems use recommender system algorithms to provide patient medical treatments. For example, a healthcare recommender system may use Collaborative Filtering to classify each disease based on symptoms and then recommend the specific physicians to the appropriate patients. Collaborative Filtering term refers to the recommendation activity. This term is still used to classify RSs. RSs are divided into three main categories to drive the recommendations: collaborative, content-based, and hybrid filtering.

##### *2.1.1.1 Different Types of Filtering Based Recommender System:*

There are three types of filtering based recommender system available:

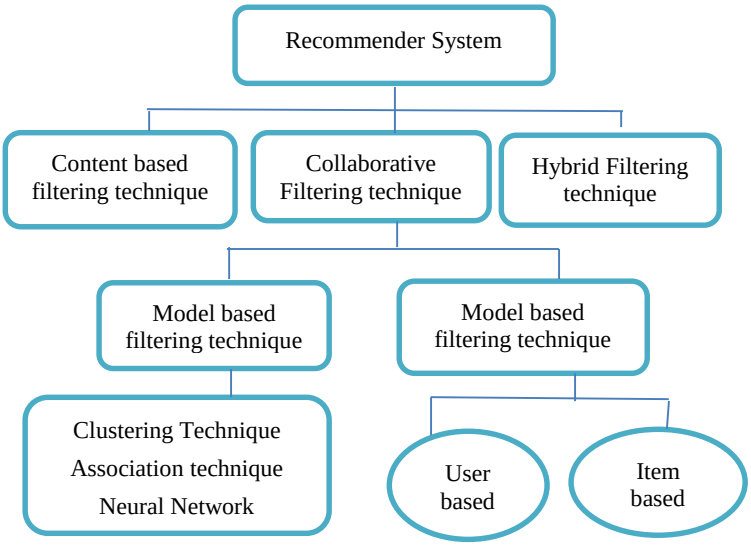


**Figure 1: Hierarchy of Recommender System based on filtering**

*a) Collaborative based Filtering Recommender System:*

First, RSs using a collaborative approach consider the user data when processing information for a recommendation. For instance, by accessing patient symptoms in the database healthcare store, the RS has access to all the patient data, such as the age, country, city, and symptoms [3]. With this information, the system can identify patients that share the same symptoms and then suggest the specific disease shared by similar patients [8].

*b) Content based Filtering Recommender System :*

Second, RSs with a content-based filtering approach base their recommendations on the item data they can access. As an example, consider a patient who is looking for a new treatment for a specific disease or symptoms using the web. When the patient browses a particular treatment (item) by specifying some symptoms, the RS gathers information about all entered symptoms and searchers in a database for all treatment that have similar symptoms [16]. The result of this search is then returned to the user as recommendations.

*c) Hybrid Filtering Recommender System:*

The third category describes RSs that combine the two previous categories into a hybrid filtering approach, recommending items based on the user and the item data in order to increase the accuracy and performance of the recommender system. For example, an RS may recommend each patient a list of family doctors according to the level of information available about them [1].

When using a collaborative or a hybrid filtering approach, RSs must gather information about the user in order to develop recommendations [12]. This activity can be done explicitly or implicitly. Explicit user data gathering happens when users are aware they are providing their information.

### 2.2 Phases of Recommender System:

**Information Collection Phase**: This phase collects vital information about patients and prepares a patient profile based on the patient's attributes, behaviors or resources accessed by the patient. Without constructing a well-defined patient profile, a recommender engine cannot work properly. A recommender system is based on inputs that are collected in different ways, such as explicit feedback, implicit feedback, and hybrid feedback. Explicit feedback takes input given by patients according to their interest in an item whereas implicit feedback takes patient preferences indirectly through observing patient behavior [16].

**Learning Phase:** This phase considers an assessment gathered in the former phase as input and processes this feedback by using a learning algorithm to exploit the patient's features as output [16, 8, 9].

**Prediction/Recommender Phase**: Preferable items are recommended for patients in this phase. By analyzing feedback collected in the information collection phase, a prediction can be made through the model, memory-based or observed activities of patients by the system [4]. The phases of the recommender system are represented in figure 2:

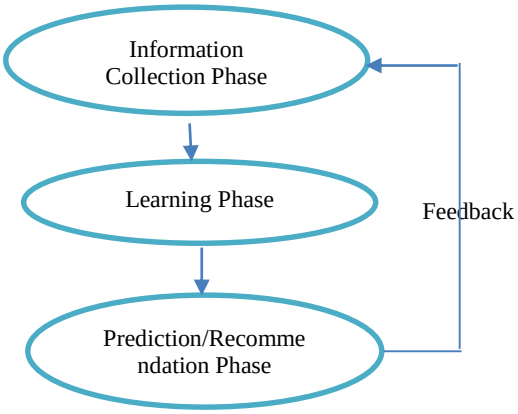


**Figure 2: Phases of recommender system**

## 2.3 Artificial Intelligence:

### *2.3.1 Introduction:*

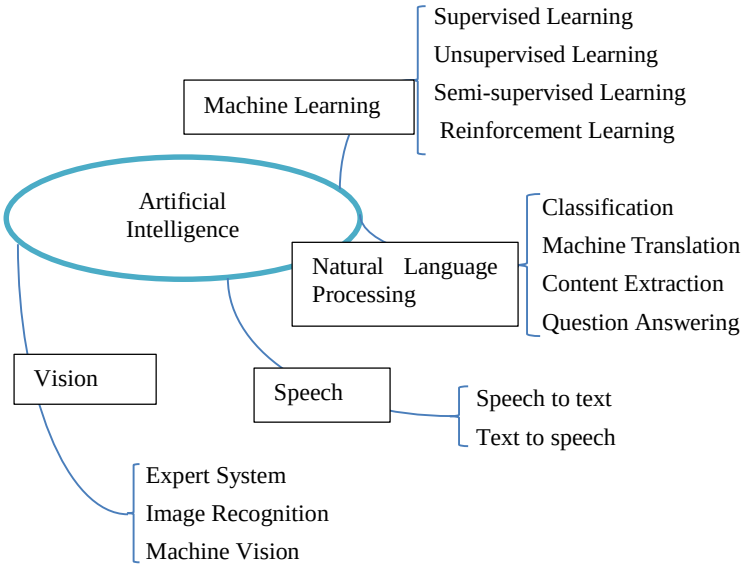


**Figure 3: Artificial Intelligence Algorithms.**

#### *2.3.1.1 Supervised Learning:*

Supervised learning happens when algorithms are provided with training data and correct answers. The task of the ML algorithm is to learn based on the training data and to apply the knowledge that was gained using real data. As an example consider an ML learning algorithm being used for book classification in a bookstore [20, 14].

Deep learning is a subset of machine learning in artificial intelligence (AI) that has networks capable of learning unsupervised from data that is unstructured or unlabeled.

As an example consider a deep learning algorithm being used for recommending medical information about the specific disease [15]. The dataset is automatically created using the discussion of doctors. The system will save the medical information in the form of a dataset, the user can do two things inside the recommender system: search for disease information and also can ask the system for disease inference and then the system will respond it according to the associated dataset.

#### *2.3.1.2 Unsupervised learning:*

In unsupervised learning, ML algorithms do not have a training set. They are presented with some data about the real world and have to learn from that data on their own. Unsupervised learning algorithms are mostly focused on finding hidden patterns in data.

For example, suppose that an ML algorithm has access to user profile information in a social network. By using an unsupervised learning approach, the algorithm can separate users into personality categories, such as outgoing and reserved, allowing the social network company to target advertising more directly at specific groups of users [6].As an example consider a text mining algorithm being used for predicting the future disease risks of patients. The system describes a recommended procedure which use similarity measures for finding relations between user's health data and medical information in order to increase patient's autonomy in their personal health and then predict future health risks by means of a recommendation technique [14].

#### *2.3.1.3 Semi-supervised Learning:*

ML algorithms can also be classified as semi-supervised learning which occurs when the algorithms work with a training package with missing information and still need to learn from it. An example is when an ML algorithm is provided with disease rankings. All patients who have not yet grasped the symptoms of a disease therefore, information is lacking. Semi-supervised learning algorithms are capable of learning and drawing conclusions even with incomplete data.

#### *2.3.1.4 Reinforcement learning:*

Lastly, ML algorithms might have a reinforcement learning approach. Reinforcement learning occurs when algorithms learn based on external feedback given either by a thinking entity, or the environment. This approach is analogous to teaching dogs to sit or jump. When the dog performs the action correctly, the dog receives a small treat (positive feedback). It does not receive any treat (negative feedback) if it performs the wrong action. As an example in the computer science field, consider an ML algorithm that plays games against an opponent. Moves that lead to victories (positive feedback) in the game should be learned and repeated, whereas moves that lead to losses (negative feedback) are avoided.

ML has become quite popular recently with the increase in processor speed and memory size. As a consequence, the field now has a large number of algorithms that use mathematical or statistical analysis to learn, draw conclusions or infer data. This number continues to increase as evidenced by the number of scientific publications that propose variations or combinations of ML algorithms. For that reason, ML algorithms have been categorized based on the purpose for which they are designed.

## 3. Systematic review

When developing RSs, software engineers must decide on the specific recommender algorithm of all those available. This choice has a significant effect on the rationale of the RS, on the data that will be needed from users and recommendation items, and on performance issues. The number of algorithm variations and combinations in the literature makes this choice a challenging task. This large number of recommender algorithms, which appears to be constantly growing and

changing, makes software engineering for RSs a continuing challenge. Trying to develop tools to make RS development easier is a moving target, as new studies must be done to observe new open problems and trends, and further enrich the knowledge base.

For these reasons, the authors conducted a systematic review to analyze the development of RSs containing AI algorithms.

The objective of this systematic review is:

1- Identify the latest trends in the use or research of AI algorithms in RSs.
2- Identify open questions in the use or research of AI algorithms.
3- Assist new researchers to position new research activity in this domain appropriately.

This review examines the following five research question:

RQ1: What are the most relevant studies addressing recommender systems?

RQ2: What problems and challenges are faced by the researchers in this field?

RQ3: What are the trends in recommender system use and research when implementing a recommender system algorithm?

RQ4: What are the trends in artificial intelligence algorithm use and research when developing a recommender system? Or what is a recommendation in the era of artificial intelligence?

RQ5: What are the trends in machine learning algorithm use and research when developing a recommender system?

The protocol for this systematic review has three main steps:

1- The first step is to gather as many publications as possible using scientific search engines. The authors then analyze the studies that were retrieved and apply an initial exclusion criteria.
2- The second step is to read the abstract of the remaining papers and apply an additional exclusion criteria.
3- The third and last step is to read the entire study and gather data from it, or apply a third set of exclusion criteria. All the data is then compiled and is used to answer the research questions discussed earlier.

**Question answers:**

1- RQ1 addresses the most relevant studies that present Hybrid RSs. We selected 20 papers as the final ones for further processing.

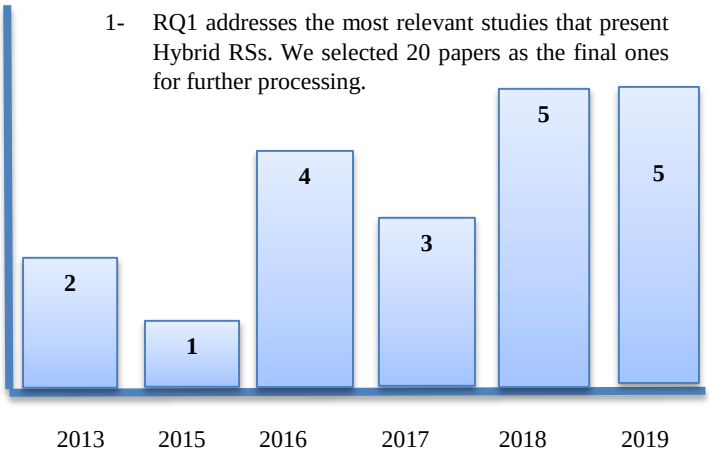


**Figure 4: Distribution of studies per publication year**

2- To answer RQ2 we summarize the most important RS problems the studies try to solve. A total of 12 problems were found. The most frequent are presented in Figure 7 with the corresponding number of studies where they appear. Studies may (and often do) address more than one problem. The same thing applies to other results (data mining techniques, domains, evaluation metrics, etc.).
3- To answer the third research question, the authors investigated the type of filtering strategy used in the recommender system being described in a study. Recommender system algorithms systems are typically classified into three categories: content-based filtering, collaborative filtering, and hybrid filtering methods.
4- The approach to answering the fourth question is that the AI algorithms may include Machine learning that we will discuss in the last question, Natural language processing, vision, speech…
The figure below describes the fields of AI:

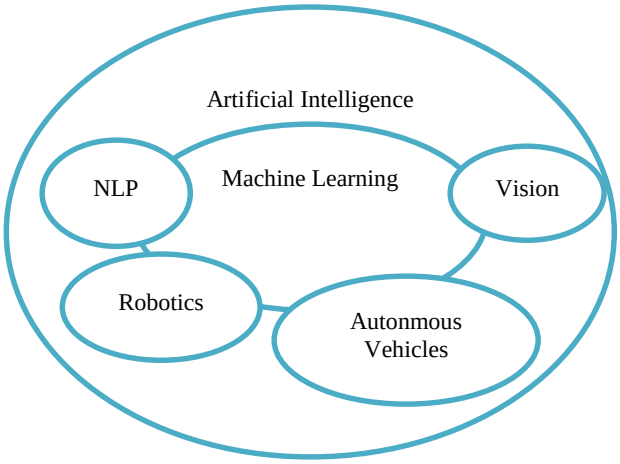


**Figure 5: Fields of AI.**

5- The answer to the last question is: there are three types of machine learning algorithms: supervised learning, unsupervised learning and reinforcement learning.

There are some synonyms that denote RSs. Based on this systematic review considers RS terms that replace "recommender" by "recommendation" and it does not consider any "artificial intelligence" synonyms.

The number of studies to be read in the systematic review is 20.

After reading the abstract of the studies, the authors were confident that 17 studies were not related to the goal of this systematic review and decided to exclude them.

## 3.1 Selection of publications reviewed in this study:

The procedure involved searching and downloading journal papers from the year 2013 to 2019 from different top-level

electronic journal databases which included Science Direct, Springer, IEEE Explore, IOS Press, Wiley, Symmetry, Elsevier, and ACM Digital Library.

These electronic journal databases were chosen because they contained published papers on the topic under review. Two sets of papers were downloaded and reviewed in this study.

In total, 20 papers were found likely to contribute to the recommender system applied in the medical domain review. The list of papers, their aims, and methods being employed were given in **table 6** :( see table at the end of the article)

*3.1.1 Recommender System Category:*

The first category of papers was those of previous related review studies in the area of recommender systems for the medical domain as well as papers related to recommendation techniques.

The purpose of this category of papers was to establish what review studies have been carried out by other authors previously as well as give a brief background of the field of recommender systems. Publications reviewed in this category included two subcategories:

- ✓ Collaborative and content-based Filtering:

The list of papers are mentioned in **table 7** :( see table at the end of the article)

- ✓ Hybrid filtering

A total of 2 papers were reviewed in this category included for related work relevant to this study which is well detailed in **table 8** :( see table at the end of the article)

*3.1.2 Intelligence Artificial Category:*

The second category consisted of papers specific to this particular study on ontology-based recommenders for the medical domain. In the second category of papers, only journal articles published from 2013 to 2019 were considered. (See **table 9** at the end of the article).

The papers were selected based on their relevance to the area under study and if they met the following inclusion criteria:

(1) Has a distinct recommendation technique(s); (2) uses ontology as one of the techniques in knowledge representation; (3) published in a top-level journal from 2013 to 2019 taking into account the impact factor of the journal where applicable.

# 4. SYSTEMATIC REVIEW RESULTS

The reading process focused on finding three types of information: one that relates to the RS being described (its classification), another that relates to the AI algorithm (its type, application domain, and performance metrics), and finally information about the source of the study (publication venue). The abstract and introduction of each paper was read, as well as the description of the proposed approach.

## 4.1 Recommender System:

Recommender systems can be classified by content-based, collaborative, or hybrid filtering. Usually, content-based approaches use the following two strategies to recommend items to users, according to classifier-based or neighbor methods. In the first method, users are associated with profiles, and a new item is presented to the classifier. The classifier then decides whether the item should be recommended or not based on the item's contents. Nearest-neighbor methods store items that the user has checked or rated and use an underlying network of items (where similar items have similar properties) to discover the user interest for a new item. Collaborative filtering RSs are subdivided in the following categories, according to neighborhood-based and model-based methods. The first method also stores the relationship user-item (the user interest for an item) in a user profile, but it uses a similarity network of users to evaluate whether a new item should be recommended. In contrast, model-based methods use the stored ratings to produce a predictive model for the user. Hybrid approaches do not seem to follow any categorization.

**Table 1: number of recommender systems algorithms studies**

| Classification of recommendation system | Number of studies | Studies |
|---|---|---|
| Collaborative filtering | 4 | [3],[12],[8],[16] |
| Content based filtering | 1 | [16] |
| Hybrid filtering | 2 | [1],[16] |

## 4.2 Artificial Intelligence algorithms:

AI algorithms can initially be classified as

➔**Machine learning algorithm:** It is a method where the target (goal) is defined and the steps to reach that target is learned by the machine itself by training (gaining experience).we have four types of machine learning algorithms: Supervised Learning, Unsupervised learning, semi-supervised learning, reinforcement learning.

➔**Natural language processing:** Natural Language Processing is broadly defined as the automatic manipulation of natural language, like speech and text, by software. One of the well-known examples of this is email spam detection as we can see how it has improved in our mail system.

➔**Vision:** It can be said as a field that enables the machines to see. Machine vision captures and analyzes visual information using a camera, analog-to-digital conversion, and digital signal processing.

➔ **Robotics:** It is a field of engineering focused on the design and manufacturing of robots. Robots are often used to perform tasks that are difficult for humans to perform or perform consistently.

However, since studies may propose more than one AI algorithm, it is more reasonable to do an analysis on the algorithm level, instead of the study one.

The table below shows the number of ML algorithms found in the studies of this systematic review that described themselves under one of these ML classifications.

There is a clear research interest in supervised learning ML algorithms for RSs. One main reason for this result is that most of the algorithms analyzed were modifications or optimization of well-known ML algorithms [5].

*4.2.1 Big Data Technologies:*

**Table 2: number of machine learning algorithm**

| Approach | Number of studies | Studies |
|---|---|---|
| Supervised learning | 7 | [19,11,14,17,20,12,9] |
| Unsupervised learning | 2 | [6,14] |
| Methaheuristic | 1 | [17] |

Table type of ML algorithm:

### *4.2.1.1 Supervised learning*

**Table 3: number of supervised learning methods**

| type of ML algorithm | Number of studies | Studies |
|---|---|---|
| SVM | 2 | [11], [20] |
| NAÏVE BAYES | 1 | [20] |
| DECISION TREE | 2 | [9], [20] |
| MATRIX FACTORIZATION | 1 | [19] |
| K NEAREST NEIGHBORS | 2 | [17], [20] |
| Convolutional Neural Network | 1 | [11] |
| Deep learning | 2 | [12], [14] |

*4.2.1.2 Unsupervised learning:*

**Table 4: number of unsupervised learning methods**

| type of ML algorithm | Number of studies | Studies |
|---|---|---|
| Data mining | 2 | [14], [6] |
| Text mining | 1 | [6] |

4.2.1.3 Search heuristic:

**Table 5: number of heuristic algorithm**

| type of search heuristic | Number of studies | Studies |
|---|---|---|
| Genetic algorithms | 1 | [17] |

## 5. EVALUATION METRICS

A major obstacle while designing recommendation systems is choosing what metrics to optimize. This can be tricky because, in a lot of cases, the goal is to NOT recommend all the same products that the user has bought before. So how we will know if the model is doing a good job at suggesting products?

### 5.1 Statistical accuracy metrics

They are used to evaluate the accuracy of a filtering technique by comparing the predicted ratings directly with the actual user rating. Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Correlation are usually used as statistical accuracy metrics. MAE is the most popular and commonly used; it is a measure of the deviation of recommendation from the user's actual value.

### 5.2 Decision support accuracy metrics

The popular ones among these are Precision and Recall. They help users select items that are more similar among the available sets of items. The metrics view prediction procedure as a binary operation which distinguishes good items from those items that are not good.

## 6. PERFORMANCE METRICS

The main goal of this systematic review is to identify the latest trend of AI algorithms used in RS development that can assist future researchers in their studies. The authors decide to take a deeper look at how the algorithms are being used by inspecting the performance metrics that researchers use to describe AI algorithms.

Statistical accuracy metrics are among the most popular performance metrics used in the studies of this systematic review, totaling almost 50% of all occurrences.

## 7. DISCUSSION

The process of literature review (Figure 5) was started with the research of leading academic databases (Science Direct, IEEE, ELSEVIER, WILEY, SPRINGER) about the Recommender System in the Medical domain and its practice. The keywords were composed of «health», «recommendation system», «recommender system in the medical domain», and «medical recommender system» .Initial refinement was made considering three criteria:

- ✓ Publication year (within 7 years: 2013-2019).
- ✓ Quality of journals (by evaluating impact factor and citation rates).
- ✓ The article found should use a recommender system algorithm or an artificial intelligence algorithm.

Then, the studies were retrieved and refined by title and abstract basis. In total, 20 papers were retrieved. It was refined to 30 papers by title basis elimination and to 25 papers by abstract-basis elimination. In the next phase, 20 papers were found meeting the following criteria of quality: reliability of the source, integrity in the content and providing applicable studies. In the final phase, finding were synthesized and reported.

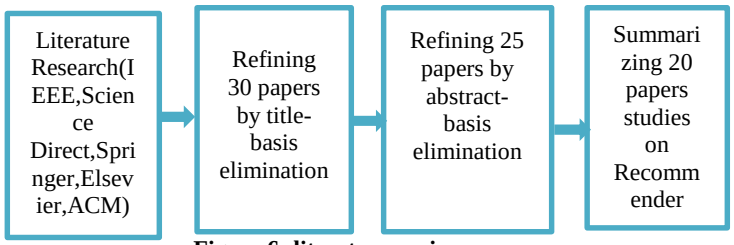


**Figure 6: literature review process**

The main issues covered in this work are presented in the schematic model of **Figure 7**(see below article). The issues are associated with the research question they belong to. In this section, we discuss the obtained results for each research question. See **table 10** below article

## 8. EXPERT OPINION:

In Summary, a lot of progress has been made in Recommender System in the medical domain to recommend treatments to the patient and to predict possible future diseases to other similar people.

At present, the Artificial Intelligence algorithm have become the mainstream for developing system that captures the symptoms, diseases, timelines, medical procedures, medications, etc., of various people and applies them to a new person who is in a similar health situation For example, if a person is feeling tired and 5 months later, he/she is identified as having diabetes and this lead to a disease a year later then this would be useful information for a new person who has the same health pattern [4]. It can automatically obtain the effectiveness identification features with high accuracy. As for "recommending items to a user with prior knowledge of some information" the recommender system algorithm is the most common method. Meantime there are important methods that are widely used to make predictions of several infectious diseases: how the disease will spread, and how to control it by combining Machine Learning and Deep learning which can also obtain an optimal results.

## 9. REFERENCES


The list of the studies inspected in this systematic review:

[1] Qiwei Han, Mengxin Ji†, Inigo Mart, ınez de Rituerto de Troya, Manas Gaur, Leid Zejnilovic. A Hybrid Recommender System for Patient-Doctor Matchmaking in Primary Care. Pages: 10, 2018.

[2] Benjamin Stark, Constanze Knahl, Mert Aydin, Karim Elish.A Literature Review on Medicine Recommender Systems. Pages: 8, 2019.

[3] Kaur, Harmanjeet and Kumar, Neeraj and Batra, Shalini. An efficient multi-party scheme for privacy preserving collaborative filtering for healthcare recommender system. Pages: 35, 2018.

[4] Tamari Rukhadze. An overview of the health care system in Georgia: expert recommendations in the context of predictive, preventive and personalised medicine. Pages: 13, 2013.

[5] Paruchuri, Venkata A.A Recommendation System for Medical Domain. Pages: 7, 2016.

[6] Dess, Danilo and Recupero, Diego Reforgiato and Fenu, Gianni and Consoli, and Sergio, A Recommender System of Medical Reports Leveraging Cognitive Computing and Frame Semantics, pages: 24, 2019.

[7] Chethan Kumar GN. Artificial Intelligence : Definition, Types, Examples, Technologies. Pages: 13, 2018.

[8] Riyaz P A, Surekha Mariam Varghese. A Scalable Product Recommendations using Collaborative Filtering in Hadoop for Bigdata. Pages: 7, 2016.

[9] Jyotirmoy Gope, Sanjay Kumar Jain. A survey on solving cold start problem in recommender systems. Pages: 6, 2017.

[10] Emre Sezgin, Sevgi Özkan. A Systematic Literature Review on Health Recommender Systems. Pages: 4, 2013

[11] Khagi, Bijen and Kwon, Goo-Rak and Lama, Ramesh, Comparative analysis of Alzheimer's disease classification by CDR level using CNN, feature selection, and machine-learning techniques.pages: 14, 2019.

[12] Abhaya Kumar Sahoo ,OrcID, Chittaranjan Pradhan ,Rabindra Kumar Barik, OrcID and Harishchandra Dubey. Deep Learning Based Health Recommender System Using Collaborative Filtering. Pages: 18, 2019.

[13] Luis Oliva-Felipe, Cristian Barrué, Atia Cortés, Emma Wolverson, Marco Antomarini, Isabelle Landrin, Konstantinos Votis, Ioannis Paliokas, Ulises Cortés. Health Recommender System design in the context of CAREGIVERSPRO-MMD Project. Pages: 8, 2018.

[14] Vidhi L. Chawda and Mahalle, Vishwanath S., Learning to recommend descriptive tags for Health Seekers using Deep Learning.pages: 7, 2017.

[15] Srinivas, Sharan and Ravindran, A. Ravi. Optimizing Outpatient Appointment System using Machine Learning Algorithms and Scheduling Rules: A Prescriptive Analytics Framework. Pages: 39, 2018.

[16] F.O. Isinkaye , Y.O. Folajimi, B.A. Ojokoh Recommendation systems: Principles, methods and evaluation. Pages: 13, 2015.

[17] Duma, Mlungisi and Twala, Bhekisipho. Sparseness reduction in collaborative filtering using a nearest neighbour artificial immune system with genetic algorithms. Pages: 16, 2019.

[18] Hanna Schäfer, Santiago Hors-Fraile, Raghav Pavan Karumur, André Calero Valdez, Alan Said, Helma Torkamaan, Tom Ulmer, Christoph Trattner. Towards Health (Aware) Recommender Systems. Pages: 5, 2017.

[19] Toly Chen, Ubiquitous Multicriteria Clinic Recommendation System.pages: 11,2016.

[20] Asri, Hiba and Mousannif, Hajar and Moatassime, Hassan Al and Noel, Thomas. Using Machine Learning Algorithms for Breast Cancer Risk Prediction and Diagnosis. Pages: 6, 2016.


**Table 6: synthesis of the articles read in this systematic review**

| Paper | Aim of the paper | Methods | Reference |
|---|---|---|---|
| A Recommender System of Medical Reports Leveraging | This paper presents a content-based recommender system within the medical domain, by providing an overview of recent information retrieval and semantic enrichment tools. It addresses the challenge to find out which types of information | Data mining, clustering | 6 |

| | | | |
|---|---|---|---|
| Cognitive Computing and Frame Semantics | can be directly processed by machines on large collections of medical reports, combining emergent cognitive computing systems in order to return reliable recommendation results. The RS implement two clustering approach to handle with various VSMs. | | |
| Ubiquitous Multicriteria Clinic Recommendation System. | This system is particularly useful for patients seeking a clinic in a region containing numerous clinics. In the proposed methodology, a patient sends a request and other related information to the system server through his/her cell phone. When this information and request are received, the system server estimates the patient's speed according to the detection results of the GPS in the patient's phone. To recommend a clinic that maximizes the utility to a patient, the system server applies the FINLP–OWA method to optimize and compare the utilities of clinics. | FINLP–OWA | 19 |
| Learning to recommend descriptive tags for Health Seekers using Deep Learning | This paper established a system that first performed a user study to analyze the health seeker needs. This provides insights of community-based health services. It then presented a deep learning scheme that is able to infer the possible diseases given the questions of health seekers. The biggest stumbling block of an automatic health system is disease inference. So if the communication between doctors that are added in this system is not done then there is the same need for manual data updating as in the existing system. So in our system also, the data updating is also depends on doctor communication. | Deep Learning | 14 |
| A Recommendation System for Medical Domain | This paper presented a recommendation system in the medical domain and it is based on case-based reasoning and sequence recognition problems. The system is very useful for both the patients and for the doctors to compare the current medical conditions of a patient with other patients and to predict the future health conditions, medications, etc. Unlike other case-based systems that are used for specific medical domains, this research considers the entire medical history of a patient to determine the possible health conditions. | Artificial intelligence | 5 |
| Sparseness reduction in collaborative filtering using a nearest neighbour artificial immune system with genetic algorithms | This paper presented an NNAISGA Nearest Neighbour Artificial Immune System with Genetic Algorithm as a partial imputation method to help improve predictions and recommendation accuracies of recommender methods in CF using datasets with sparsity. The idea was to present a method that can reduce sparsity in datasets without the need to scale the data. The NNAIS part of the method created, proliferated and optimized antibodies. The GA part performs further optimization over a few cycles to strengthen the antibodies. | Genetic algorithm<br>Nearest Neighbor | 17 |
| An efficient multi-party scheme for privacy preserving collaborative filtering for healthcare recommender system | This paper proposes a multi-party ADD technique for the healthcare recommendation system which is based on randomization, masking and holomorphic encryption technique having low computation cost.it proposes (Privacy-Preserving Collaborative Filtering) PPCF scheme on ADD based on multi-party random masking and polynomial aggregation techniques. | Collaborative Filtering | 3 |
| Using Machine Learning Algorithms for Breast Cancer Risk Prediction and Diagnosis | This paper tries to compare the efficiency and effectiveness of those algorithms in terms of accuracy, precision, sensitivity, and specificity to find the best classification accuracy. SVM has proven its efficiency in Breast Cancer prediction and diagnosis and achieves the best performance in terms of precision and low error rate. | Machine Learning | 20 |
| A Systematic Literature Review on Health Recommender Systems | In this study, a literature review on Health Recommender Systems was conducted, and the findings were presented. The main conclusion is that HRS Health Recommender System is a promising development for healthcare services. The studies demonstrated that HRS has been branched out in different fields of the health industry, and HRS applications have been increasingly embedded in the health service systems. | Recommender system algorithm | 10 |
| Health Recommender System design in the context of CAREGIVERSPRO-MMD Project | This paper provides an outline of a health recommender system designed in the context of the project to provide tailored interventions to care givers and people living with dementia. It presents an overview of the undertaken solution approach to design the Health Recommender System. This system provides two different services: a ranked list of interventions that are tailored to the user's preferences and requirements and a list of potential acquaintances according to their similarities to the given user. Although both functionalities provided by the system share similar components and interfaces towards data sources, their objectives and the nature of the items that each one handles, differ. | Recommender system algorithm | 13 |

| | | | |
|---|---|---|---|
| A Hybrid Recommender System for Patient-Doctor Matchmaking in Primary Care | In this paper, partnered with a private healthcare provider to design a matchmaking mechanism between patients and primary care doctors in order to promote continuity of care. More specifically, it describes the matchmaking process as five distinct use cases adjusted to the different levels of information that may be available about a patient. it adopts a hybrid approach that aims to provide a unified solution that presents all patients with a list of personalized doctor recommendations | Hybrid algorithm | 1 |
| A Scalable Product Recommendations using Collaborative Filtering in Hadoop for Bigdata | This paper gives scalable product recommendations collaborative filtering for Bigdata on a Hadoop-based processing system. An optimized HBase gives better performance. For low latency applications, HBase is highly preferred because of distributed architecture and leverage the power of Apache Hadoop. As the size of data increases the Hadoop performs well by adding more data nodes into the processing. | Big Data algorithms | 8 |
| A survey on solving cold start problem in recommender systems. | The purpose of this paper is to familiarize people with the cold start problem in recommender systems and its available solutions. The problem is still open for a better solution and interested researchers can initiate this research work in this direction. Hybridization of the two explicit and implicit techniques for better solutions to the cold start problem may be an interesting problem for researchers. | Collaborative filtering | 9 |
| An overview of the health care system in Georgia: expert recommendations in the context of predictive, preventive and personalised medicine | The main aim of this paper is to present the current statistics and situation of the health care system in Georgia; the changes in the transition period within the society and the health care system. Also presented are the efforts from the Government and the Ministry of Labour, Health and Social Affairs of Georgia in the way of numerous initiatives and activities in order to improve the quality care of patients and sustain the health care system. This paper described the institutional framework, process, content, and implementation of health and health care policies in Georgia in the context of predictive, preventive and personalized medicine. | Recommender system algorithm | 4 |

**Table 7: articles that use Collaborative and content based Filtering technique**

| Methodology | Study | Goal | Method Used | Advantages | Limitations |
|---|---|---|---|---|---|
| Collaborative filtering and Content based filtering | [3] | People can submit their symptoms to the healthcare system. The RS can identify the disease from symptoms and then recommend the physicians to them. | Privacy preserving | Less online-computation cost and balance is maintained between parameters accuracy, privacy and efficiency | High off-line computational cost, the scheme cannot be applied on numeric ratings |
| | [12] | As people use social networks to understand their health condition, so the health recommender system is very important to derive outcomes such as recommending diagnoses, health insurance, clinical pathway-based treatment methods and alternative medicines based on the patient's health profile. | Restricted Boltzmann Machine (RBM)-Convolutional Neural Network (CNN) deep learning method | The proposed RBM-CNN demonstrates better accuracy of the health recommender system as compared to others | We need to provide better accuracy with a high level of privacy. |
| | [17] | This paper gives scalable product recommendations collaborative filtering for Bigdata on a Hadoop-based processing system. | Comparison between HBase and | An optimized HBase gives better performance. For low latency applications, HBase is highly preferred because of distributed architecture and leverage the power of Apache Hadoop | lack of scalability and efficiency problems |

**Table 8: articles that use Hybrid Filtering technique.**

| Methodology | Study | Goal | Method Used | Advantages | Limitations |
|---|---|---|---|---|---|
| Hybrid Filtering | [1] | In this work, we partnered with a private healthcare provider to design a matchmaking mechanism between patients and primary care doctors in order to promote continuity of care. More specifically, we describe the matchmaking process as five distinct use cases adjusted to the different levels of information that may be available about a patient. And then, we adopt a hybrid approach that aims to provide a unified solution that presents all patients with a list of personalized doctor recommendations. | hybrid matrix factorization | Our results show superior predictive accuracy compared to both the heuristic baseline and a classical CF recommender system | cold start problem |

**Table 9: articles that use artificial intelligence techniques.**

| Methodology | Study | Goal | Method Used | Advantages | Limitations |
|---|---|---|---|---|---|
| Machine Learning Algorithm | [19] | The goal of this study is to enable patients to compare multiple clinics, the study proposes a ubiquitous multicriteria clinic recommendation system.in this system, patients can send a request through their all phones to the system to obtain a clinic recommendation. | Fuzzy integer nonlinear programming (FINLP) Approach | The effectiveness of clinic recommendations can be further enhanced by cooperation among different clinics. However, this is based on the premise that these clinics are willing to cooperate and provide more operating information, such as availability and the average waiting time, to the ubiquitous multicriteria clinic recommendation system | the system server has to justify when the received information is incomplete |
| | [11] | Use image processing has proven to be an efficient, potential tool for the detection and diagnosis of a tumor, brain lesion, cancer, and Alzheimer's disease. | SVM,CNN,KNN | This article presents an efficient approach, to use the fine-tuned pertained (or once scratch trained) CNN for feature extraction, and getting an optimal number of features to classify using a simpler machine-learning model that proves to be worthy in sense of classification accuracy, time-efficient, and hardware optimization. | difficulty in the choice of the parameter in deep learning |
| | [14] | This paper established a system that first performed a user study to analyze the health seeker needs. This provides insights of community-based health services. It then presented a deep learning scheme that is able to infer the possible diseases given the questions of health seekers. The biggest stumbling block of an automatic health system is disease inference. | Hidden layers, Data Mining Deep Learning | ⇨ Using SVM: the advantage is: a valuable and useful tool for making classifications<br>⇨ Using a Decision Tree: The diagnosis of a disease has been investigated showing good levels of correctness. | ⇨ Using SVM: They lack the natural explanatory value.<br>⇨ Using a Decision Tree: |

| | | | | | |
|---|---|---|---|---|---|
| | | So if the communication between doctors that are added in this system is not done then there is the same need for manual data updating as in the existing system. | | ⇨ Using Deep Learning: user will get accurate information for its query | It mostly uses for identifying heart disease only.<br>⇨ Using Deep Learning: User not get answer in case of insufficient data. |
| | [20] | The goal of this system is to try to compare the efficiency and effectiveness of those algorithms in terms of accuracy, precision, sensitivity, and specificity to find the best classification accuracy | Data mining and machine learning methods | SVM has proven its efficiency in Breast Cancer prediction and diagnosis and achieves the best performance in terms of precision and low error rate. | No Limitations |

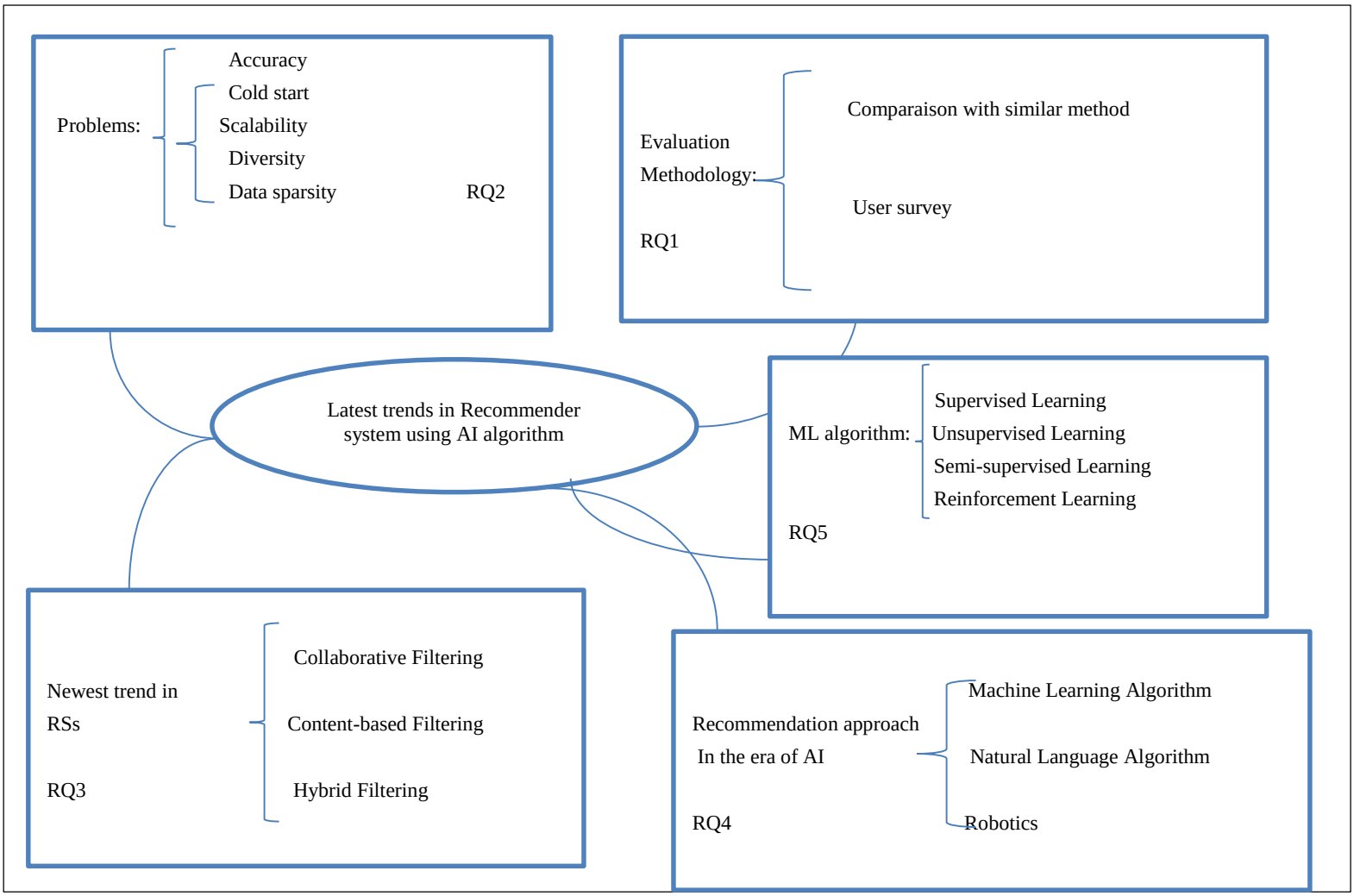


***Figure 7: Recommenders Systems and higher-order themes***

**Table 10:** ***Problems and possible solutions***

| Problems | Possible Solutions | References |
|---|---|---|
| Cold-start | Use association rule mining on the item or user data to find relations that can compensate for the lack of ratings. Mathematical constructs for feature extraction and a combination of different strategies can also be used. | [1],[16] |
| Sparsity | Use the few existing ratings or certain item features to generate extra pseudo ratings. Experiment with Matrix Factorization or Dimensionality Reduction. | [19] |
| Accuracy | Use Fuzzy Logic or Fuzzy Clustering in association with CF. Try putting together CF with CBF using Probabilistic Models, Bayesian Networks or other mathematical constructs | [19], [11], [14], [17], [20], [9] |
| Scalability | Try to compress or reduce the datasets with Clustering or different measures of similarity. | [3], [12], [8] |
| Diversity | Try modifying neighborhood creation by relaxing similarity (possible loss in accuracy) or use the concept of experts for certain item tastes. | [17], [20], [9] |